FAILURE MECHANISM ANALYSIS OF REINFORCEMENT GEOSYNTHETICS WITH CYCLIC LOADING TO CONSIDER SEISMIC CONDITION

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ABSTRACT

Usually, the life times of geogrids are assessed as the long-term creep behavior which causes shape deformation and collapse of the slopes and embankments. During an earthquake the structure is subjected to additional loads, which may influence the creep characteristics of the reinforcement. SIM test provides an opportunity to study the effect of simulated seismic events or the influence of other additional loads, occurring at different intervals of the life of the structure, on the long-term strength of geosynthetic reinforcement. In this paper, two simulated seismic SIM tests were performed, one with a simulated seismic event at 23 ℃ step, the other tests carried out after 79 ℃ step. Creep strain decreased after seismic event cause of recovery force, then strain increased again. After same condition of seismic event in different times, strain finally overlapped.

Keywords: Seismic event, creep, SIM

INTRODUCTION

During an earthquake the structure is subjected to additional loads, as may be the case with mining subsidence, blast loading or the application of abnormal loads, which may influence the creep characteristics of the reinforcement. Accelerated creep test, the stepped isothermal method (SIM), has been widely used to evaluate the creep behavior of geogrids. These tests can typically be performed in one day and use a single specimen, loaded continuously whilst being exposed to a sequence of timed isothermal events of increasing temperature. The development of the SIM test provides an opportunity to study the effect of simulated seismic events or the influence of other additional loads, occurring at different intervals of the life of the structure, on the long-term strength of geosynthetic reinforcement. In this paper, two simulated seismic SIM Tests were performed, one with a simulated seismic event at 23 ℃ step, the other tests carried out after 79 ℃ step. The reason for varying the time of application of the simulated seismic load was to study the effect of the timing of real life earthquakes. The purpose of this experiment is to assess the SIM procedure to identify the effect of simulated seismic events on the creep mechanism of geosynthetic reinforcement. The second was to quantitatively calculate creep reduction factor considering seismic event and to reflect this in the design property.

EXPERIMENTAL

A 10 ton/m woven type geogrid (WG-10) was used in this experiment. The creep behavior of the geogrids was evaluated using stepped isothermal test methods. Five isothermal exposures of 23, 37, 51, 65, 79 °C were employed for the SIM procedure. The creep tests were performed at 40, 50 and 60% of ultimate tensile strength (UTS). For simulate seismic event, 80, 90 and 100% of UTS applied to middle of 23 °C step and after 79 °C step individually. The additional load was applied for a period of 1min. The total creep tests conditions show in Table 1.

RESULTS AND DISCUSSIONS

Figure 1 shows creep strain response to linear time recorded for reference SIM test at 40% of UTS. Strain of the PET geogrid exhibits an initial decrease at each elevated temperature step. This behavior is most likely caused by the thermal shrinkage of the PET filament. Figure 2 shows procedure to generate a creep master curve. Figure 2 (a) shows the rescaled creep curve. The initial part of each curve is affected by the thermal shrinkage of the test specimen, that portion of the curve is eliminated (Fig. 2 (b)). The creep master curve is then generated by horizontal and vertical shifting, as shown in Fig. 2 (c).

Table 1 Creep tests conditions

Items	
Temperature (°C)	23, 37, 51, 65, 79
Loading level (%)	40, 50, 60
Isothermal duration	3 hrs
Seismic condition loading level (%)	80,90,100
Seismic duration	1 min
Additional loading time	1.Midway through the 23°C temperature cycle 2.After 79°C temperature

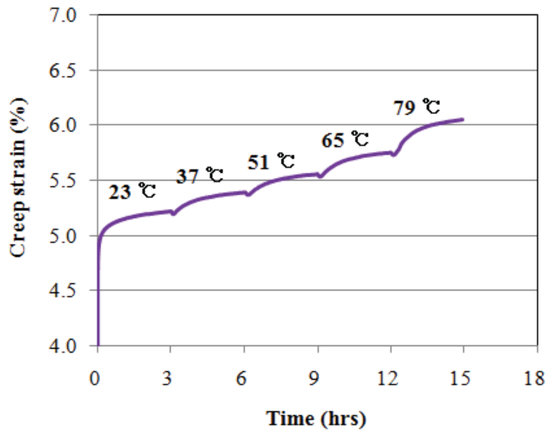

Fig. 1 Creep response vs. linear time recorded for reference SIM test.

Figure 3 shows creep strain vs. log time at various stress conditions. The creep strain increases linearly with log time and creep rupture was detected at 70-100% applied loads. After graphically showing the result of creep rupture with applied stress over rupture time, the applied stress at 10^6 hours of design term was obtained through regression analysis and the reduction factor was obtained by the comparison of this value with the UTS. Figure 4 shows regression analysis diagram. It can be seen that dots are almost on straight line and the reduction factor was 1.55.

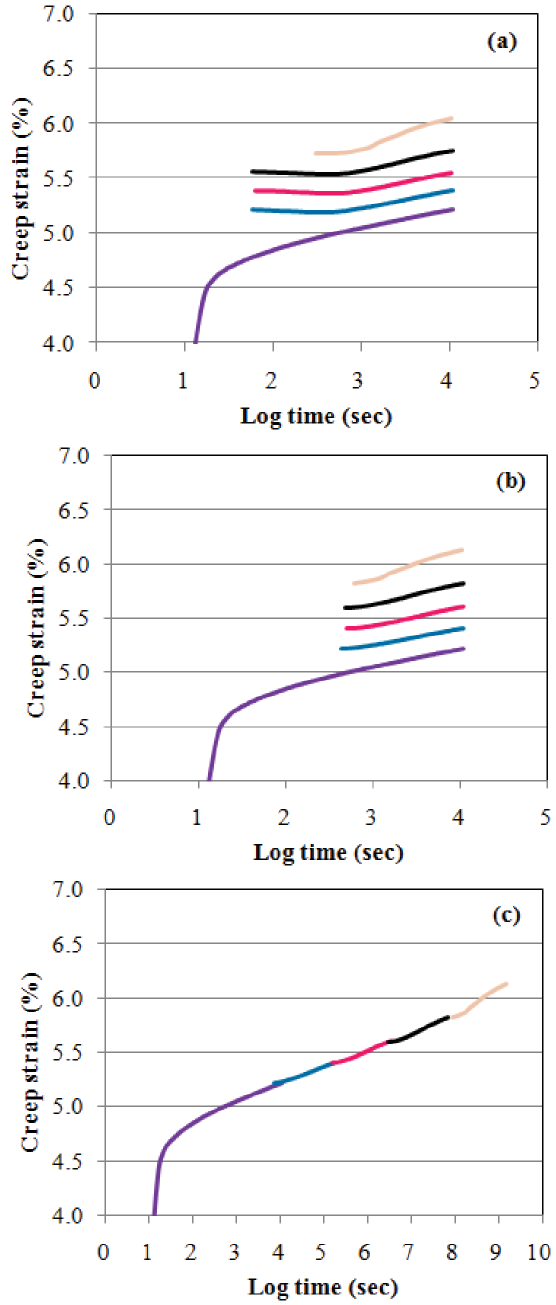

Fig. 2 Procedure to generate a creep master curve.

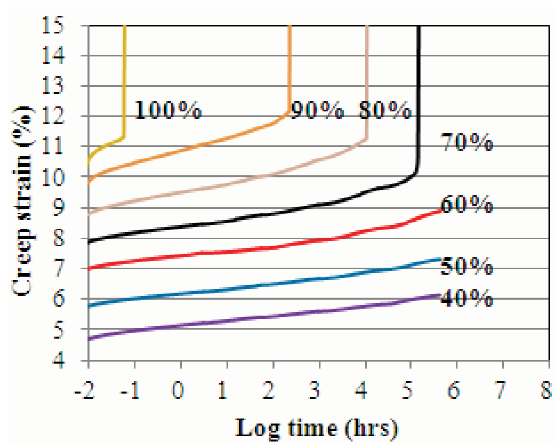

Fig. 3 Creep properties of WG-10.

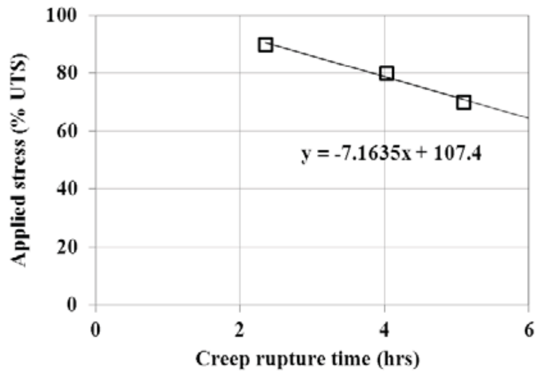

Fig. 4 Plot of applied stress vs. creep rupture time.

The creep response resulting from the application of the seismic load midway through 23 ℃ temperature cycle is shown in Fig. 5. The application of the seismic load produced an immediate strain of approximately 5.6%, followed by a strain recovery of 2.6% on removal of the load. It is apparent that the temperature increase to 65 ℃ step had no effect on the creep response, remaining constant until the commencement of 79 °C step. The final strain was approximately 8%. The creep response of the application of the seismic load after the 79 °C temperature cycle is shown in Fig. 5. Creep strain exhibits an initial decrease at each elevated temperature step. This behavior is most likely caused by the thermal shrinkage of the PET filament. The final strain was approximately 7.9%, similar value as that obtained from the application of the seismic load midway through 23 °C temperature cycle. Shift factor at each step derived from reference SIM test (Table 2), and these shift factor are directly used to make creep master curve at seismic event. Fig. 6 shows creep master curve vs. log time recorded for seismic SIM Test, using a constant load of 40, 50% and 60% of the ultimate tensile strength and a simulated seismic event total loading equivalent to 80, 90 and 100% of UTS applied for 1 min midway through 23°C temperature cycle. Creep strain slightly decreased at 40% of UTS till 65 °C steps after seismic event and began to increase 79 °C step. Creep strain rate is very slow after seismic event, so recovery force makes long time shrinkage. Creep strain slightly decreased at 50% of UTS till to 103 hours and increased. Creep strain rate at 50% UTS is quicker than 40% of UTS after same seismic event. So shrink time of 50% of UTS is shorter than 40% of UTS is loaded. In contrast creep strain increased at 101 hours at 60% of UTS.

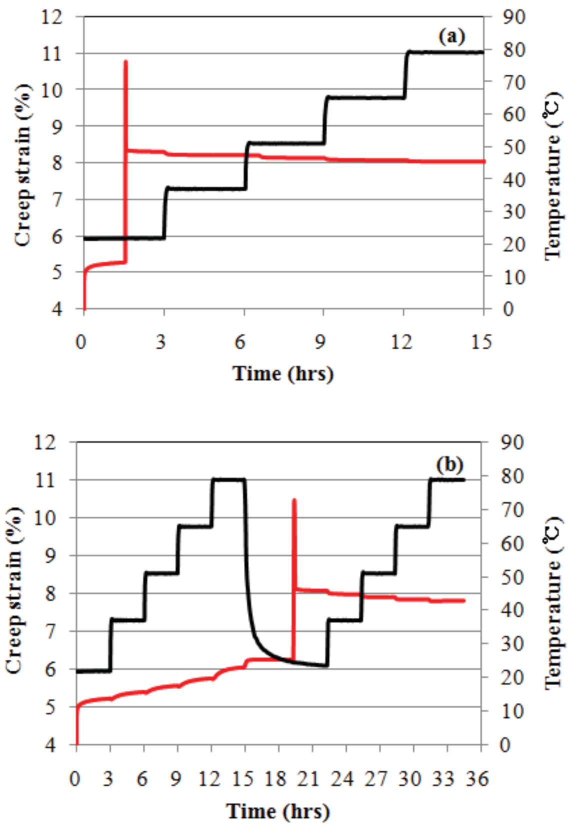

Fig. 5 Creep response vs. linear time recorded for seismic SIM Test; (a) 100% of UTS applied for 1 min midway through the 23℃ temperature cycle (b) 100% of UTS applied for 1 min after the 79℃ temperature cycle.

Table 2. Shift factor

Temperature step (℃)	Shift factor
23	0
37	1.25
51	2.5
65	3.8
79	5.15

Figure 7 shows rescaled creep strain vs. log time recorded for seismic SIM Test, using a constant load of 40, 50% and 60% of the ultimate tensile strength and a simulated seismic event total loading equivalent to 80, 90 and 100% of UTS applied for 1 min midway after 79 ℃ temperature cycle (48years). The test results shows similar trend with seismic event at 23 °C steps. Fig. 8 shows creep master curve vs. log time recorded for seismic SIM Test, using a constant load of 40, 50% and 60% of the ultimate tensile strength and a simulated seismic event total loading equivalent to 80, 90 and 100% of UTS applied for 1 min midway after 79 ℃ temperature cycle. SIM method can successfully predict creep strain after seismic event which may happen after any years. After seismic event initial strain slightly decreased. However, final strain overlaps with original creep strain. While before overlap it may need long times and reduction factor may change.

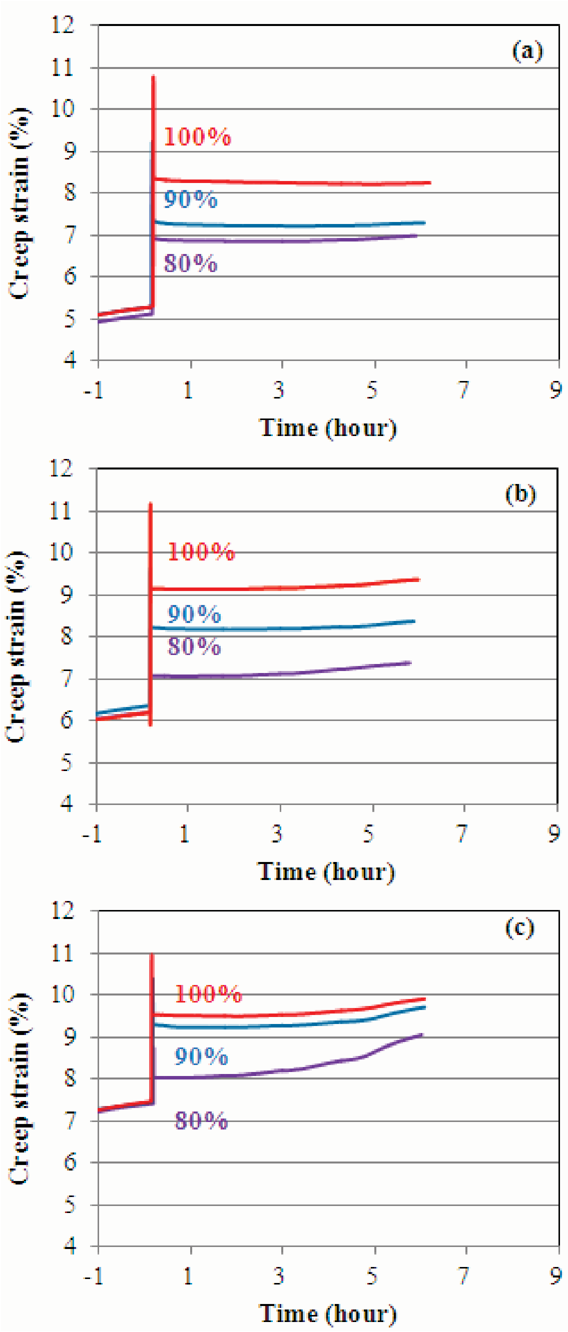

Fig. 6 Creep master curve vs. log time recorded for seismic SIM Test, using a constant load of (a) 40%. (b) 50% and (c) 60% of the ultimate tensile strength and a simulated seismic event total loading equivalent to 80, 90 and 100% of UTS applied for 1 min midway through the 23℃ temperature cycle.

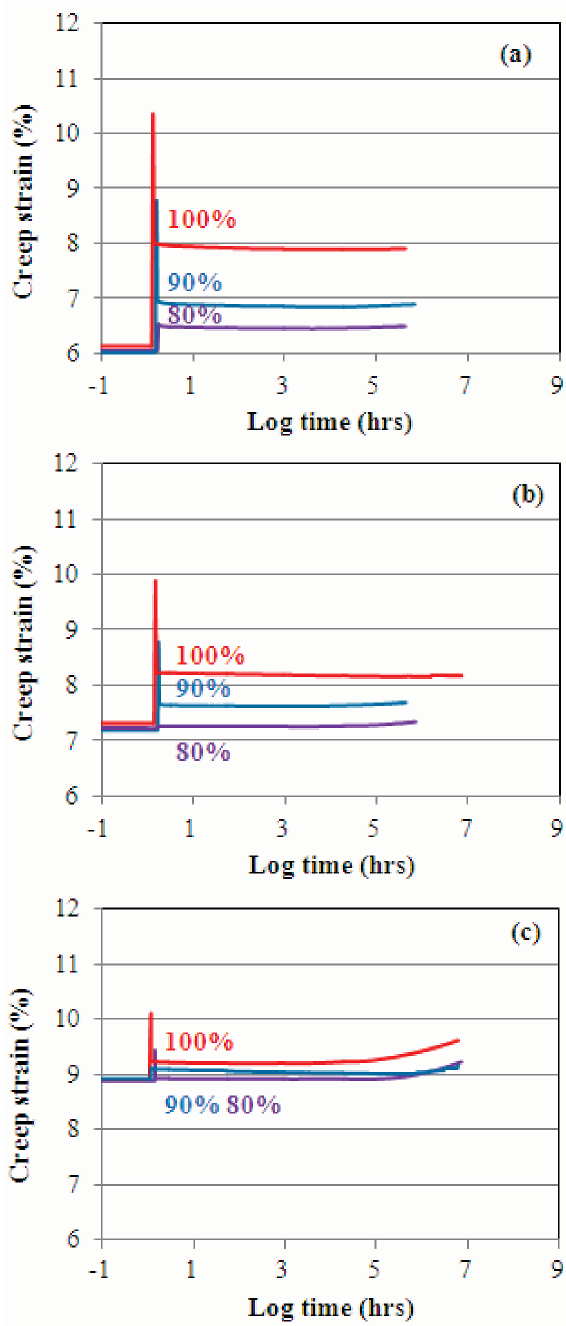

Fig. 7 Re-scaled creep curve vs. log time recorded for seismic SIM test after the 79 ℃ temperature cycle (48 years).

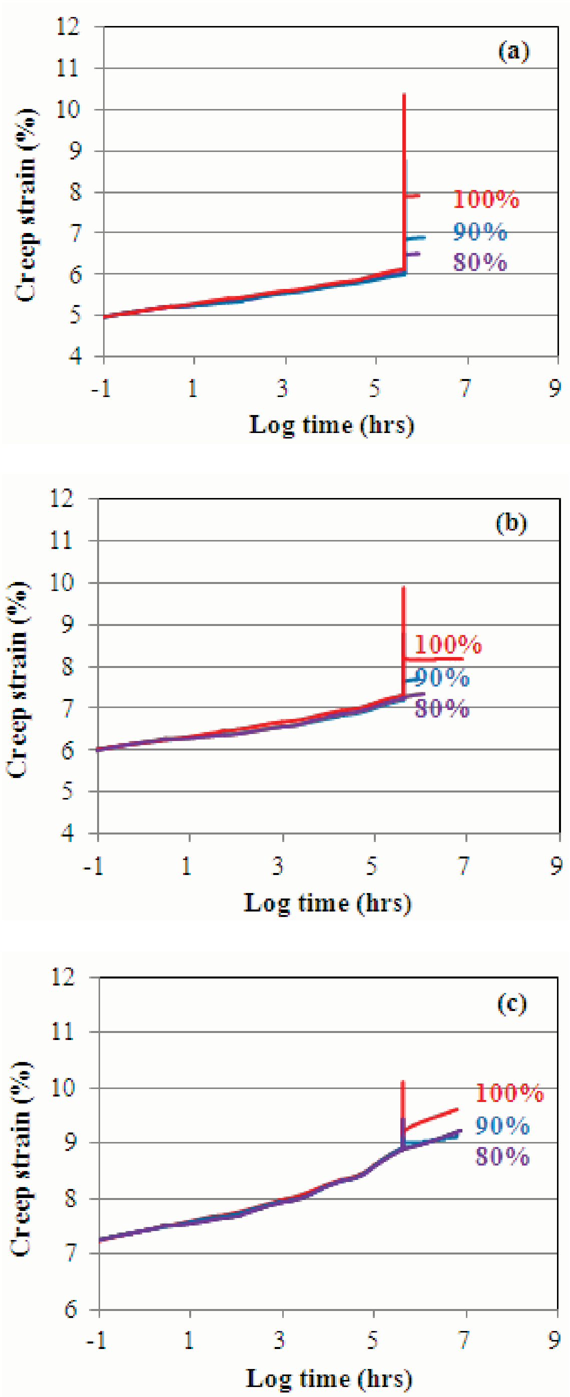

Fig. 8 Creep master curve vs. log time recorded for seismic SIM Test; using a constant load of (a) 40%. (b) 50% and (c) 60% of the ultimate tensile strength and a simulated seismic event total loading equivalent to 80, 90 and 100% of UTS applied for 1 min after the 79℃ temperature cycle.

Table 3 shows ultimate tensile strength before and after creep test. There was no change in tensile strength and slightly decreased in strain after creep test or creep test at seismic event. Both of tensile strength and strain decreased after creep test (60% of UTS) at seismic event at 100% load. It is predicted that some filament destroyed at serious condition. Moreover, slippage at clamp or man-made mistake may happen in creep test.

Table 3 Ultimate tensile tests

Test no.	Simulated seismic loading	Equivalent UTS (kN/m)	Strain at failure (%)	Comments
1	No	107.5	10.8	
2	No	105.2	9.3	Virgin material 40%
3	Yes	107.7	9.2	SIM 40% to 80%
4	Yes	91.5	7.8	SIM 60% to 100%

CONCLUSIONS

Creep property of geogrid simulated seismic event was tested using SIM test method. Creep strain decreased after seismic event cause of recovery force, after that strain increased again. After same condition of seismic event in different times, strain finally overlapped. Normally seismic event nearly no effect on long-term property. But in specific condition, seismic event may reduced creep property.

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